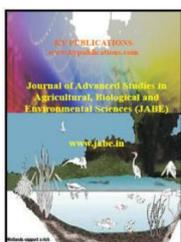


**PHYSICO-CHEMICAL CHARACTERIZATION OF DRINKING WATER BOREHOLES IN AFIKPO AND UNWANA TOWNS OF EBONYI STATE, NIGERIA****ABEL A. ORJINTA¹, DAMIANA A. AMATOBI² & GLORIA O. UMEZURUIKE³**^{1, 2}DEPARTMENT OF CIVIL ENGINEERING TECHNOLOGY, AKANU IBIAM FEDERAL POLYTECHNIC UNWANA³DEPARTMENT OF SCIENCE LABORATORY TECHNOLOGY, AKANU IBIAM FEDERAL POLYTECHNIC UNWANA[DOI: 10.33329/jabe.64.12](https://doi.org/10.33329/jabe.64.12)**ABSTRACT**

Drinking water boreholes are a major source of drinking water in Nigeria. Since most of the borehole systems do not incorporate water treatment facilities, continual evaluation of their water quality is paramount for the protection of public health. However there is dearth of data on water quality of drinking water boreholes on which to base the assessment. This study therefore provides a baseline data for continual evaluation of physico-chemical water quality of water-boreholes in Afikpo and Unwana Towns of Ebonyi State, Nigeria. Water samples were collected from boreholes in seven communities and were analysed for 22 physico-chemical parameters, using detailed standard laboratory procedures. The results are: pH (5.2 to 8.1, mean-6.6), conductivity (74 to 999 $\mu\text{S}/\text{cm}$, mean-613 $\mu\text{S}/\text{cm}$), turbidity (2.02 to 7.06 NTU, mean-3.79 NTU), colour (4 to 5 TCU, mean-5TCU), total hardness (4 to 52 mg/l, mean-13mg/l), calcium hardness (3.92 to 46.12mg/l, mean-11.51mg/l), magnesium hardness(0.58 to 5.32mg/l, mean-1.96mg/l), chloride (7.60 to 29.22 mg/l, mean-12.47mg/l), Sulphate (1.57-8.36, mean-3.15mg/l), nitrate(0.19 to 2.04mg/l, mean-0.60mg/l), free chlorine(0.00 to 0.06mg/l, mean-0.03mg/l), Fe(0.04 to 0.08 mg/l, mean-0.06mg/l), Mg(13.40 to 26.40mg/l, mean-18.71mg/l), Zn(0.01 to 1.54 mg/l, mean-0.26mg/l), Pb(0.12 to 0.22mg/l, mean-0.18mg/l), Ca(3.74 to 8.40mg/l, mean- 6.05mg/l), Mn(0.01 to 0.14mg/l, mean 0.06mg/l), Ni(0.02 to 0.05mg/l, mean-0.03mg/l), Cr(0.02 to 0.13 mg/l, mean-0.05mg/l), Na⁺(13.27 to 41.19mg/l, mean-27.07mg/l), K⁺(26.37 to 46.16mg/l, mean-37.97mg/l) and Cu(0.17 to 0.30mg/l, mean-0.20mg/l). Lead, Nickel and Free Chlorine did not meet the WHO and NSDWQ safe drinking water limits. The study recommends a further examination of concentrations of Lead and Nickel in drinking water-boreholes in Afikpo North Local Government Area.

Keywords: *Characterization, Health, Public, Standard, Quality, Water-borehole***1.0 Introduction**

Human need for drinking water has no substitute. However, the accessibility and safety of drinking water need to be continually monitored because drinking water contaminated by pathogens, toxic chemicals, or radiological substances poses health risks to water consumers (World Health Organization [WHO], 2019a). A minimum of 2 billion people worldwide, according to the WHO's (2019b) estimate, consume water contaminated with faeces every year. The result is prevalence of waterborne diseases such as "diarrhoea, cholera, dysentery, typhoid, and polio," with diarrhoea disease alone causing 485, 000 deaths annually (ibid). Exposure to natural or anthropogenic chemical contaminants in drinking water is also a significant health



risk to consumers. For instance drinking water contaminated by arsenic led to a loss of 9100 lives in Bangladesh in 2001 (Lokuge, Smith, Caldwell, Dear & Milton, 2004).

Systems processes and methods which facilitate continual provision of adequate and safe drinking water can be seen as a worthwhile contribution towards improvement of human life. Data on water quantity and water quality are required for making right decisions for provision of adequate and safe drinking water. Modern societies encourage the provision of adequate and safe drinking water to their citizens by maintaining structured water supply systems and control mechanisms. Nonetheless, the absence of functional public water supply, combined with poor water quality control systems across Nigeria has made alternative or self-help water supply sources inevitable. The self-help water supply sources in Nigeria include rivers, streams, ponds, springs, rainwater harvesting devices, dug wells and boreholes. Typically, these self-help sources have no treatment facilities, and no quality control measures. Therefore there is likelihood that many self-help water supply sources in Nigeria could be provide unsafe drinking water. Thus the health and general wellbeing of human communities which depend on self-help sources for their drinking water are at high risk.

In Nigeria, over 69 million (over 30%) of the population still lack access to clean drinking water (United Nations Children Fund [UNICEF], 2018). There is gross inadequacy of municipal water supplies; and the water borehole is flourishing as alternative source of drinking water. It is seemingly becoming more feasible and affordable; for many individuals to sink water boreholes in their residences or close to point of use. Borehole drillers are no longer in shut supply, water boreholes have become a common household assets for many Nigerians who can afford a bungalow and bigger houses in both the rural and urban areas. Kumolu (2012) observes that every intending property owner in Nigeria considers a water borehole as a necessary alternative to government's inability to provide potable municipal water supplies to citizens. A major advantage of the boreholes is that they can be powered with small petrol/diesel generators, and can relatively provide reliable water supply all the year round. Also when properly constructed, protected and maintained, the process regulated and the water quality adequately monitored, water borehole can provide good quality drinking water for many Nigerians who do not have access to municipal water supplies. However there are concerns about the proliferation, operation and water quality of boreholes in Nigeria.

Apparently, there is uncontrolled and unregulated proliferation of water boreholes across neighborhoods in Nigeria. The former Nigerian Minister of Water Resources, Suleiman Adamu, observed that the proliferation of boreholes in Nigeria is becoming uncontrollable to the extent that households drill water boreholes within three meters interval (Okogba, 2017). The Minister was quoted as saying that "[water borehole] drilling activities have been hijacked by quacks, it's an all-comers affair, we need to start emphasizing that regulation is key, all borehole practitioners must get their permits to protect our groundwater sources" (PM News, 2018). Concerns about water boreholes in Nigeria largely centre on environmental and health consequences. Some experts worry that indiscriminate drilling of boreholes can have adverse hydro-geological conditions of the underground water system, and may lead; to landslides, earth tremors or even earth quakes, and reduction of soil fertility (Okeke,2018).

While the exact nature and magnitude of environmental problems which can be caused by unprofessional and indiscriminate drilling of boreholes in Nigeria remains a matter of debate among experts. What is obvious is that improperly constructed and poorly managed water-boreholes portend a great danger to human health. Being a ground water, a properly constructed and operated water-borehole may contain little or no microbial contaminant, yet a water borehole is prone to pollution by naturally occurring chemicals (WHO, 2011).A water-borehole can also be contaminated by human activities through release of wastes and



chemicals to the adjoining environment; for example via dumpsites, septic tanks, underground chemical tanks, etc. Since the natural and human activities which can pollute ground water tend to be sporadic, it can be a good proactive measure to regularly assess water-boreholes, to characterize water quality parameters against recommended safe drinking water standard limits, as a way to avoiding the consumption of contaminated water and protecting public health.

The quality parameters of water-boreholes have attracted the interest of many researchers in Nigeria in recent years. Researchers have evaluated water quality of water-boreholes in different parts of Nigeria based on the bacteriological and physico-chemical examination of contaminants. Adeleke, Kafeelah, Olumuyiwa and Mutiu (2016) assessed water-borehole samples from 20 households in Lagos-Ogun axis of Southwestern Nigeria. They examined the water samples for the presence of contaminants which included silver, iron, manganese, lead, nickel, magnesium, cadmium, zinc, sodium, potassium, pH, turbidity, dissolved oxygen, electrical conductivity, alkalinity, total hardness, chloride, nitrate and sulphate. After comparing their findings with the WHO Standards they concluded that “nineteen of the twenty household water samples were found to fall short of the ideal water quality suitable for lifetime use.”

Okereke, Ogbonnaya, and Eze (2014) studied 32 water-boreholes in Aba South Local Government area of Abia State of Nigeria and observed that the physico-chemical and bacteriological water quality parameters of some of the water-boreholes suggested frequent pollution of groundwater by household waste and sewage. They also noted high levels of bacterial counts in the water samples and concluded that most of the water-boreholes are not safe for human consumption.

OkoyeEne, and Ojobor (2016) examined the physical, chemical and microbiological qualities of water samples from ten water-boreholes in Enugu and concluded that the water samples from water-boreholes did not meet the overall acceptable WHO Standards and were not safe for drinking.

Odikamnoru, Omowaye and Aneke (2014) carried out bacteriological and physico-chemical examination of water samples of water-boreholes in Abakaliki metropolis, Ebonyi State Nigeria. They concluded that the bacteriological and physico-chemical parameters implied that “all the Abakaliki borehole water did not meet the WHO Standards and should be treated or boiled before drinking.”

Enoh, Eneche, and Uko (2016) conducted micro element assessment on six water-borehole sources in Oso Edda, Afikpo South L.G.A of Ebonyi State and identified the concentration of Cadmium (Cd), Lead (Pb), Nickel (Ni), Arsenic (As) and Chromium (Cr). They concluded that the water-borehole sources of water posed no health risk to residence of Oso Edda, but recommended a further analysis on the water-borehole sources of water “in order to identify the concentration of other heavy metals and possibility of other contaminants.”

Studies on water-borehole water quality parameters in Nigeria have not reached a general agreement concerning the level of contamination or health risks associated with water supplies from the water-boreholes. The findings on water-borehole water quality studies tend to reflect the peculiarity of the study environment. However there is a consensus of recommendations on the need for proactive and preventive actions to be continually taken to ascertain, monitor, and control the quality of all water-borehole water supplies in Nigeria and by so doing protect public health.

This study aims to provide reference data, including the methodologies for measuring and monitoring the physico-chemical quality of drinking water from water-boreholes spread across the Afikpo North Local Government Area of Ebonyi State in South Eastern Nigeria. The entire community of Afikpo North Local



Government Area has no public water system, and so most depend on private water-boreholes for drinking water supplies. The objective of the study includes the determination of physico-chemical water quality of major drinking water-boreholes spread across the communities in the study area and comparison of the results with the limits set by the WHO (2004) and the Nigerian Standard for Drinking Water Quality [NSDWQ],(2007). The research focuses on water-boreholes selected from seven communities spread across the local government area: Amaizu, Amuro, Mgbom, Ngodo, Ndibe, Akanu Ibiam Federal Polytechnic Unwana and Unwana Community. As a proactive measure, this research can be of immense health benefit to the study area communities, where more than 80% of the staff and students of Akanu Ibiam Federal Polytechnic Unwana reside. The study can form the basis for making right decisions towards safeguarding the public health of over 150 000 inhabitants most of whom currently use as drinking water the untreated water from water-boreholes whose quality has never been ascertained.

2.0 Materials and Methods

2.1 The Study Area

The Study area is Afikpo North Local Government Area of Ebonyi State, Nigeria. By the Nigeria's 2006 census Afikpo North Local Government Area has a population of 156,611 people (National Bureau of Statistics, 2013). It occupies a land area of about two hundred and forty square kilometers. Afikpo, the headquarters of the Local Government Area can be located in a map on latitude 6 degrees North and Longitude 8 degrees East. Vegetation of the study area can be described as a mixture of open grass land and tropical rain forest. The major occupation of people in the area is farming, as the climate favours rice, yam and cassava production. The Study area also contains a sizeable number of traders, artisans, staff of organized private sector and staff and students of the Akanu Ibiam Federal Polytechnic Unwana [AIFPU]- one of Nigeria's foremost tertiary institutions. Over 80% of the staff and students of AIFPU reside at Afikpo and Unwana Towns. The entire Afikpo North Local Government Area has no municipal drinking water supplies. Apart from a few hand operated water-boreholes provided by government and intervention agencies, people in the study area depend mostly on private alternatives (mainly surface water, rainwater and water-boreholes) for their drinking water supply. The water-borehole source is usually the most patronized source for direct drinking water by households in the study area.

Drinking water supply is not regulated, and water quality is not usually monitored in Afikpo North Local Government area. Thus there is no water quality data for assessing water quality of drinking water sources and for proactively protecting public health in the study Area. Hence there is need to characterize the water boreholes to provide data for water quality monitoring in different communities in the study area. Samples were collected from seven communities namely: Amaizu, Amuro, Mgbom, Ngodo, Ndibe, Akanu Ibiam Federal Polytechnic Unwana and Unwana Community. Figure 2.1 is a map of Afikpo North Local Government Area of Ebonyi State Nigeria.

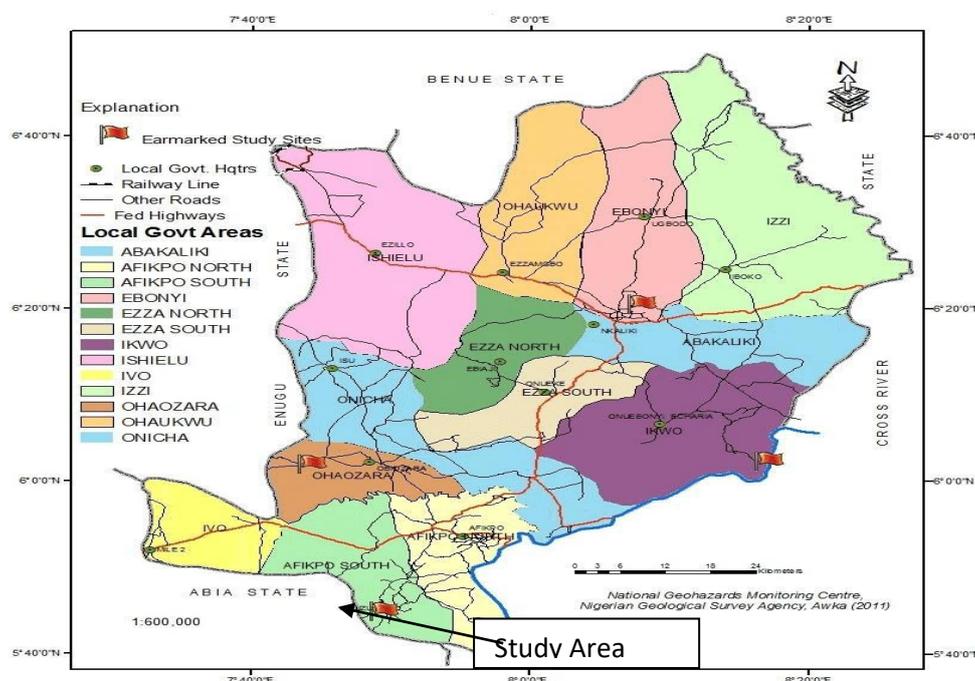


Figure 2.1: Map of Afikpo North Local Government Area of Ebonyi State Nigeria

Retrieved from: https://www.researchgate.net/figure/Administrative-map-of-Ebonyi-State-Source-National-Geohazards-Awka_fig1_307608865

2. 2 Sample Collection

Water samples were collected from seven drinking water-boreholes spread across communities in the study area. Each water-borehole was sampled once weekly for five consecutive weeks, making a total of 35 samples that were collected and analysed in laboratories for physico-chemical water quality. The samples were collected in clean sterilized bottles having stoppers. Each bottle was rinsed 3 times with water from a selected sampling water-borehole before a sample was collected, and subsequently labeled, indicating the source, date, and time of collection. The sample was transferred to the laboratory within seven days of collection for physico-chemical examination.

2.3 Laboratory Tests

Each of the 35 samples was subjected to standard laboratory water quality tests for drinking water on 22 physico-chemical parameters. The physico-chemical water quality parameters that were determined include pH, conductivity, turbidity, colour, total hardness, calcium and magnesium hardness, chloride, sulphate, nitrate, free chlorine and metals:- Fe, Mg, Zn, Pb, Cu, Mn, Ni, Cr, Na⁺, K⁺, and Ca.

2.3.1 Determination of pH of Water Sample

The pH of the sample was determined using electrometric method (United Nations Environment Programme [UNEP]/WHO, 1996).



2.3.1.1 Apparatus

The apparatus used were: a digital pH meter (Wellcows pH meter, 0-14 range and incorporating automatic temperature compensation- 0 to 80 °C) with electrode (probe), beakers; soft tissue paper, and glass rod.

2.3.1.2 Reagents

The reagents used were: pH buffer solutions of pH 4, pH 7, and pH10, and distilled water.

2.3.1.3 Procedure

The electrode was rinsed with distilled water, blotted and dried with soft tissue paper, and then calibrated with the buffer solutions listed above. The electrode was again rinsed with distilled water, blotted and dried. The water sample was poured into the beaker, mixed and stirred with glass rod. Then the electrode was inserted into the water sample, ensuring that it did not touch the bottom of the beaker. The pH value was read when digital display on the meter stabilized to a number. The procedure was repeated three times and the average value was calculated and recorded.

2.3.2 Determination of Conductivity

The electrical conductivity of water samples was determined using electrochemical method (Globe, 2014).

2.3.2.1 Apparatus

The apparatus used were a conductivity meter (LOHAND, CD-304: 100-19900 $\mu\text{s}/\text{cm}$ range, ATC- 0 to 50 °C) with electrode and four clean 100-ml beakers, thermometer and soft tissue.

2.3.2.2 Reagents

The reagents used were distilled water and a standard solution of 0.01MKCL.

2.3.2.3 Procedure

The electrode was rinsed in distilled water and gently blotted dry with soft tissue. The standard solution was poured into each of the two clean beakers to a depth of about 2cm then the meter was switched on and its electrode put into the first beaker and stirred for about 2 seconds. Then the electrode was removed and transferred to the second beaker and gently stirred until the display read out to a value of 1413 microSeimens per centimeter.

Water samples were poured into the third and fourth clean 100ml beakers, each to a depth of 2cm. The electrode of the conductivity meter was again rinsed in distilled water and gently blotted dry with soft tissue. The conductivity meter's electrode was immersed into the third beaker and stirred for about 2 seconds. The electrode was then removed and was immersed on the fourth beaker and stirred gently until the display stabilized. The conductivity value was read directly in microseimens per centimeter ($\mu\text{s}/\text{cm}$) in the digital readout. The procedure was repeated three times after every 10 minutes and the average value was calculated and recorded.

2.3.3 Determination of Turbidity of Water Samples

Turbidity of the water samples was determined by Nephelometric method.



2.3.3.1 Apparatus

The apparatus used include turbidimeter (OaktonT-100 Waterproof Turbidimeter, 0-1000 Nephelometric Turbidity Unit [NTU] range) with sample vial, vial cap, and light shield cover.

2.3.3.2 Reagents

Reagents include standard stock solutions of 20.0, 100, and 800 NTU.

2.3.3.3 Procedure

The turbidimeter was calibrated with the above listed stock solutions according to manufacturer's instructions. The instrument was turned off and placed on a flat surface. Water sample was filled above the fill mark on the sample vial after which the vial was covered with a vial cap. The sample vial was placed inside the sample well on the turbidimeter, and aligning the index marks on vial with the mark on the meter, the vial was pushed down to seat. Then the light shield cover was placed over the vial to entirely cover it. The turbidimeter was turned on, and turbidity of the sample was read directly in NTU in the instrument display read - out.

2.3.4 Determination of Colour

The colour of water samples was determined by Platinum-Colbat method (American Public Health Association [APHA], 1992).

2.3.4.1 Apparatus

The apparatus used include Nessler tubes- matched, 50-mL, tall form (Kimble® 45315A-50 KIMAX®, s), 1000ml beaker, electronic weighing scale, inert stoppers, and centrifuge.

2.3.4.2 Reagents

The reagents used included distilled water, conc HCL, and potassium chloroplatinate (K_2PtCl_6).

2.3.4.3 Procedure

One hundred milligrams (100ml) of conc. HCL was added to 200ml of distilled water in a beaker. A measure of 1.246g of K_2PtCl_6 and 1.00g of crystallized cobaltous chloride ($CoCl_2 \cdot 6H_2O$) were dissolved in the distilled water and conc. HCL mixture. The resulting mixture was diluted with distilled water to 1000ml mark in a beaker to obtain a standard stock solution of equivalent colour unit of 500. Twelve 50 ml nessler tubes were selected and labeled N1 to N12. Then 12 different measures of the colour standard stock solution were added to the labeled nessler tubes in the sequence: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 6.0, and 7.0 ml; for N1 to N12 respectively. Then the nessler tubes were diluted with distilled water to 50 ml. This resulted to colour standards of 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, and 70. The colour standards were protected by fitting inert stoppers. Turbidity in water sample was removed by centrifuging the sample until the supernatant became clearer. A matched nessler tube with the water sample up to 50ml mark was compared with the standards; by looking vertically downwards through the tubes towards a specula or white surface positioned for light to be reflected through the column of the liquid. The matched colours then indicated the estimated colour of the diluted samples.



TRUE COLOUR UNITS (TCU) WERE CALCULATED AS FOLLOWS:

$$TCU = \frac{E \times 50}{V} \quad (2.1)$$

WHERE, E = ESTIMATED COLOR OF A DILUTED SAMPLE AND V= ML OF DILUTED SAMPLE.

2.3.5 Determination of Total Hardness

Total hardness in the water samples were determined using EDTA titrimetric method.

2.3.5.1 Apparatus

The apparatus used for determination of total hardness include burette, pipette, funnel and beakers.

2.3.5.2 Reagents

The reagents used were 0.1N HCL, Ethylene diamine tetra-acetic acid (EDTA). Erichrome T indicator and buffer solution of pH 10.

2.3.5.3 Procedure

Fifty milligrams of the sample was measured into a clean beaker. Then 0.5ml of 0.1N HCL was added to the sample. The solution was heated to boiling point to expel CO₂, and then cooled to 50°C and 2ml of buffer solution and two drops of Erichrome T indicator was added. The resulting solution was titrated with EDTA standard titrant until a colour change from red to blue was obtained. The volume of EDTA used was recorded and the overall procedure was repeated three times and a mean value was recorded.

Total hardness was calculated as follows:

$$Total\ hardness(mg/l\ CaCO_3) = \frac{ml\ of\ EDTA\ titrant \times f \times 1000 \times 0.1 \times 17.8}{ml\ of\ sample} \quad (2.2)$$

Where f = multiplication factor =1.

2.3.6 Determination of Calcium Hardness

Calcium hardness in the water samples were determined using EDTA titrimetric method.

2.3.6.1 Apparatus

The apparatus used for determination of calcium hardness were: burette, conical flask, funnel, beakers, pipette, and measuring cylinder.

2.3.6.2 Reagents

The reagents were EDTA 0.2N, sodium hydroxide (NaOH) solution 4N, and Erichrome T indicator.

2.3.6.3 Procedure

Fifty milligrams of sample were measured into a clean beaker and one milligram of sodium hydroxide was added. Then Two drops of Erichrome T indicator were added. The solution was thoroughly mixed and titrated with EDTA standard solution until the colour changed from purple to violet. The volume of EDTA used in the titration was recorded. The procedure was repeated three times and a mean value was recorded.

Calcium hardness was calculated as follows:



$$\text{Calcium hardness (mg/l CaCO}_3) = \frac{\text{mlofEDTA titrant} \times 1000}{\text{mlof sample}} \quad (2.3)$$

2.3.7 Determination of Magnesium Hardness

The difference between the total hardness and calcium hardness gave the magnesium hardness.

2.3.8 Determination of Chloride

Chloride was determined using Argentometric method.

2.3.8.1 Apparatus

The apparatus used were: burette, conical flask, stirring rod, beakers and measuring cylinder.

2.3.8.2 Reagents

The reagents were: standard silver nitrate (AgNO₃) 0.01N solution and potassium chromate (K₂CrO₄) indicator solution.

2.3.8.3 Procedure

One hundred milligrams (100ml) of water sample were poured into a 25ml conical flask; 1ml of potassium chromate indicator solution was added. The resulting solution was titrated with 0.1M standard silver nitrate solution until a permanent golden brown colour was obtained at pH range of 7 to 10. The volume of silver nitrate used in the titration was recorded. Chloride in mg/l was calculated as follows:

$$\text{Chloride (mg/l Cl}^{-1}) = \text{mlof AgNO}_3 \times 9.87 \times 5 \quad (2.4)$$

2.3.9 Determination of Sulphate

Sulphate in the water samples was determined using turbidimetric method.

2.3.9.1 Apparatus

The apparatus used include spectrophotometer, magnetic stirrer, stop watch, measuring spoon, volumetric flask, conical flasks, measuring cylinders and beakers.

2.3.9.2 Reagents, preparations and Treatment

The reagents include glycerol, conc. HCL, distilled water, 95% ethanol solution, sodium chloride, Barium chloride crystals, anhydrous Na₂SO₄,

2.3.9.2.1 Preparation of conditioning reagents

The conditioning reagent was prepared by forming a solution in a beaker with 300ml of distilled water, 30ml of conc. HCL, 75g sodium chloride and 50ml of glycerol; then adding slowly 30ml conc. HCL and mixing.

2.3.9.2.2 Preparation of Sulphate Standard Solution (100ml/l)

The sulphate standard solution was prepared by mixing 0.147g of the anhydrous Na₂SO₄ in distilled water in a volumetric flask and diluted up to 1000ml mark. The resulting solution was equivalent to sulphate standard solution of 100mg/l.



2.3.9.2.3 Preparation of Calibration Standard

Calibration sulphate standard solutions of 5, 10, 15, 20, 25, 30, 35 and 40 mg/l were prepared by diluting each measure of the Sulphate standard solution (5, 10, 15, 20, 25, 30, 35 and 40ml) to 100ml with distilled water in a volumetric flask.

3.3.9.2.4 Treatment of Calibration Standards

The calibration standards were treated by measuring 100ml of each calibration sulphate standard solution into 250 ml conical flask, adding 5ml of the conditioning reagent and mixing in the stirring apparatus. While stirring a spoonful of BaCl₂ crystals (about 0.3ml) was added with the stop watch switched on spontaneously. The solution was stirred at constant speed and after one minute, the solution was immediately poured into the absorption cell and the absorbance was read at 425nm in the second minute. Readings of all the other concentrations were taken, and a plot of absorbance against concentration called the calibration curve, was obtained as in figure 2.2 below.

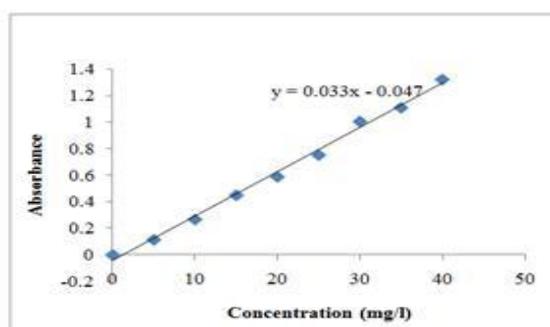


Figure 2.2: Sulphate Standard Calibration Curve

Source: Field Survey

2.3.9.3 Procedure

A measure of 100ml water sample was poured into a 250ml conical flask, and 5ml of conditioning agent was added. The solution was mixed in the stirring apparatus. While stirring at a constant speed a spoonful of BaCl₂ was added and the stop watch was started. After exactly one minute some the solution was poured into absorption cell and read at 425nm in the second minute. The sulphate (SO₄²⁻) was obtained by extrapolation from the calibration curve or using the equation of the curve where y is the absorbance of the sample and x, the concentration of sulphate (mg/l) to be determined.

2.3.10 Determination of Nitrate

Nitrate in the water samples was determined using UV-spectrophotometer method.

2.3.10.1 Apparatus

The apparatus used were UV-spectrophotometer, filter paper, Nessler tube, volumetric flasks and beakers.

2.3.10.2 Reagents, Preparations and Treatment

The reagents were distilled water, Potassium Nitrate, CHCl₃/L (chloroform), conc. HCL



2.3.10.2.1 Preparation of Nitrate Stock Solution

KNO_3 was dried in the oven at 105°C for 24 hours. 0.7215g of the dried KNO_3 was dissolved in distilled water and diluted to 100ml. The stock solution was preserved with 2ml CHCl_3/L (chloroform). Then 1.00ml of the stock solution was equivalent to $100\mu\text{gNO}_3\text{-N}$.

2.3.10.2.2 Preparation of Nitrate Standard Solution

Fifty milligrams (50ml) of stock solution was diluted with distilled water to 500ml. One milligram (1.00ml) of the resulting solution was equivalent to $10\mu\text{gNO}_3\text{-N}$.

2.3.10.2.3 Preparation of 1M HCL

Thirty milligrams (30ml) of conc. HCL was diluted to 1000ml in a volumetric flask.

2.3.10.2.4 Preparation of Calibration Standards

Volumes of 0, 1, 2, 3, 4, 5, 6, and 7 ml were put in different beakers, and each volume was diluted with distilled water to 50ml. The resulting solution was equivalent to 0, 50, 100, 150, 200, 250, 300, and $350\mu\text{gNO}_3\text{-N}/50\text{ml}$. Each standard was treated by adding 1M HCL.

2.3.10.2.5 Treatment of Sample

Sample was treated by adding 1M HCL to 50ml clear sample and mixing thoroughly.

2.3.10.3 Procedure

The spectrophotometric measurements were taken by reading absorbance or transmission against distilled water set at zero absorbance or 100% transmission. A wave length of 220nm was used to obtain $\text{NO}_3\text{-N}$ reading at a wave length of 275nm to determine interference due to dissolved organic matter. Twice the absorbance reading at a wavelength of 275nm was subtracted from reading at a wavelength of 220nm to obtain absorbance value due to NO_3 . The absorbance value of $\text{NO}_3\text{-N}$ was then extrapolated from the standard calibration curve shown in figure 2.3 below.

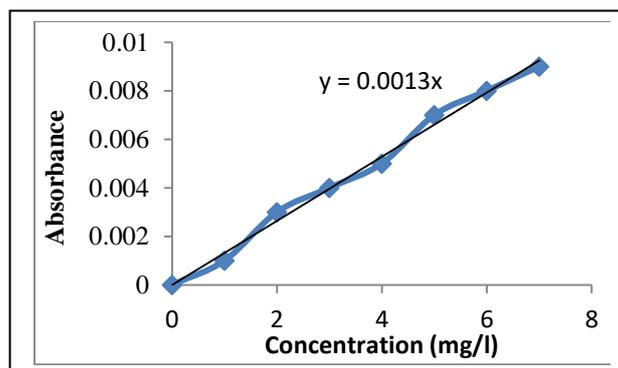


Figure 2.3: Nitrate Standard Calibration Curve

Source: Field Survey

2.3.11 Determination of Residual/Free Chlorine

Residual/free chlorine in the water samples was determined using diethyl-penthlene-diamine (DPD) method.



2.3.11.1 Apparatus

The apparatus used were: Hatch Pocket Colorimeter II, clean sample cell, cap, chlorine meter scale and clippers.

2.3.11.2 Reagents

The reagents were: DPD free chlorine reagent powder pillows and demineralized water.

2.3.11.3 Procedure

The colorimeter was operated according to manufacturer's instructions. Demineralized water sample (the blank) was poured into a 10ml clean sample cell to fill it and then capping it. The instrument was switched on and meter indicated low range channel (LR); meter cap was removed and the blank was placed in the cell holder with the diamond mark facing the keypad; meter cap was replaced to cover the cell and blank compartment; ZERO/SCROLL button was pressed and the display showed "0.00"; Then the meter cap was removed and the blank sample cell detached from the cell holder. Another 10ml clean sample cell was prepared by filling it with water sample; the contents of one DPD free chlorine reagent powder pillow added to the sample cell; the sample cell capped, and the contents gently shaken for about 2 seconds. The sample cell was placed in the cell holder and covered with the instrument cap. The READ/ENTER button was pressed on, and free chlorine in mg/l was read on the instrument's display read - out.

2.3.12 Determination of Mg, Fe, Mn, Ni, Zn, Pb, Cr, and Cu.

The concentration of Mg, Fe, Mn, Ni, Zn, Pb, Cr, and Cu in the water samples were determined using the Atomic Absorption Spectrophotometer (AAS) method.

2.3.12.1 Apparatus

The apparatus consisted of AAS machine (model 68000, Shimadzu, Japan.), hollow cathode tubes, pressurized air, acetylene, volumetric flask beakers, and filter mesh.

2.3.12.2 Reagents

The reagents used included metals (salts representing those mentioned above), acidified distilled water, HCL.

2.3.12.3 Digestion of Water Samples

Five milligrams (5ml) of HCL were added to 100ml of water in a beaker. The beaker was heated in a hot plate in a fume cupboard until the volume was reduced to about 20ml. It was then allowed to cool to room temperature and filtered into a volumetric flask. The volumetric flask was filled to 100ml mark with distilled water.

2.3.12.4 Procedure

For each sample, 100ml of water sample were digested. A hollow cathode lamp for each metal was installed in the AAS machine and the wavelength characteristics of the metal were set according to manufacturer's instruction. The machine was switched on and until the energy stabilized. The oxidant and fuel gases (air and acetylene) were then allowed to flow and ignite while the rates were adjusted according to manufacturer's instruction. Acidified distilled water was then aspirated and the aspiration rate was adjusted after which the instrument was set to zero. Then calibration standards of the metal, the blank and the digested sample solutions were aspirated one after the other and the absorbances obtained were recorded.



Concentration of analytes in mg/l of the digested samples was extrapolated from prepared calibration curves shown in figures 2.4 to 2.11 below.

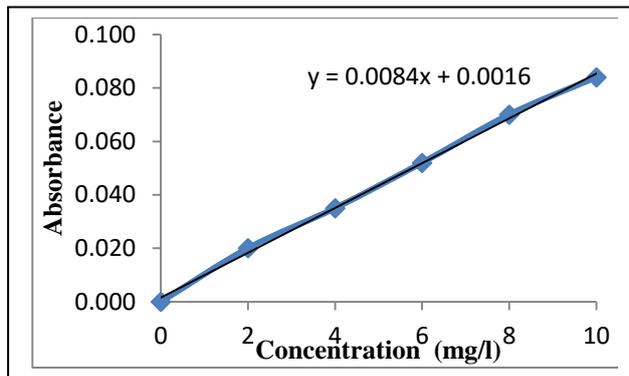


Figure 2.4 Magnesium Standard Calibration Curve.
Source: Field Survey

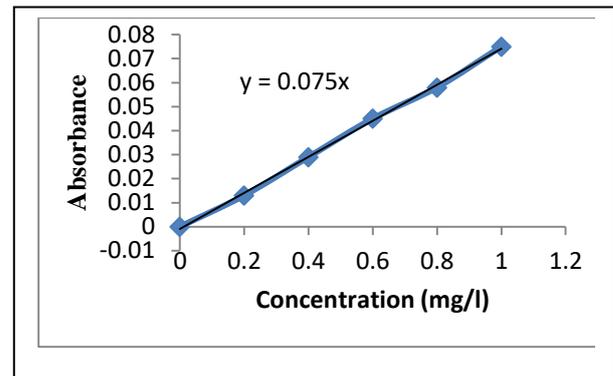


Figure 2.5 Iron Standard Calibration Curve
Source: Field Survey

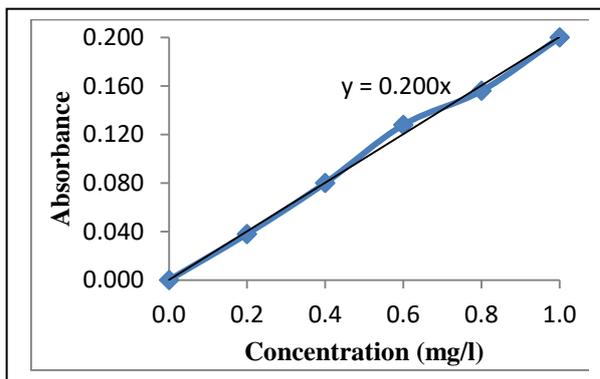


Figure 2.6 Manganese Standard Calibration Curve
Source: Field Survey

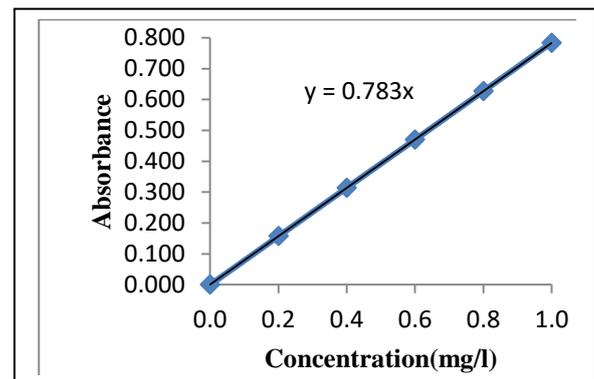


Figure 2.7 Nickel Standard Calibration Curve
Source: Field Survey

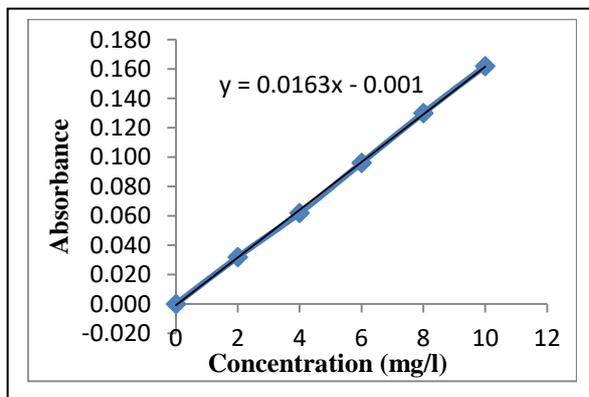


Figure 2.8 Zinc Standard Calibration Curve
Source: Field Survey

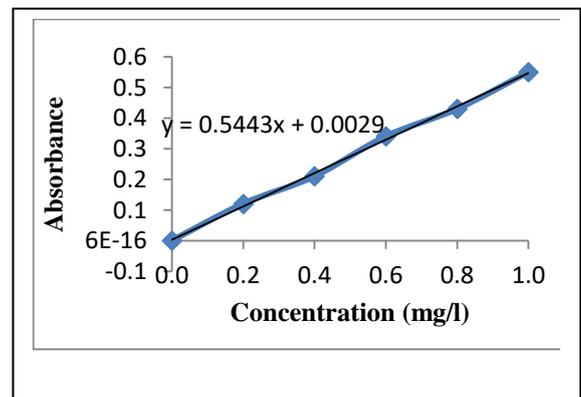


Figure 2.9 Lead Standard Calibration Curve
Source: Field Survey

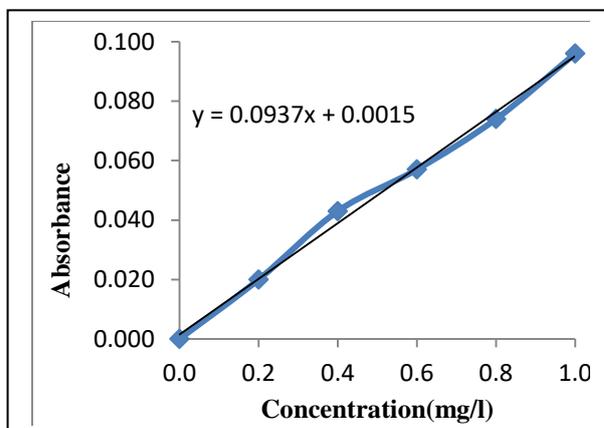


Figure 2.10 Chromium Standard Calibration Curve

Source: Field Survey

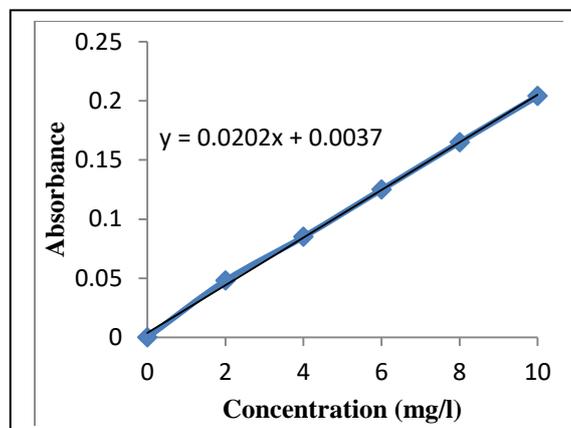


Figure 2.11 Copper Standard Calibration Curve

Source: Field Survey

2.3.13 Determination of Na, K and Ca

The metals Na, K and Ca were determined using flame photometric method.

2.3.13.1 Apparatus

The apparatus used were: Flame photometer (FLAPHO) instrument, volumetric flasks and glass pipettes.

2.3.13.2 Reagents

The reagents used were: stock solutions of Na⁺, K⁺ and Ca⁺.

2.3.13.3 Procedure

One hundred milligrams of water samples were digested. Calibration standards of 2,4,6,8 and 10 mg/l were prepared for sodium and potassium while 5, 10, 15, 20, 25 and 30 mg/l were prepared for calcium. The instrument was operated according to manufacturer's instruction. The absorbance of the samples, calibration standards and the blank were then measured and recorded. Calibration curves were drawn, one for each of the metals. The concentrations of the metals were then extrapolated from calibration shown in figures 2.12 to 2.14 below.

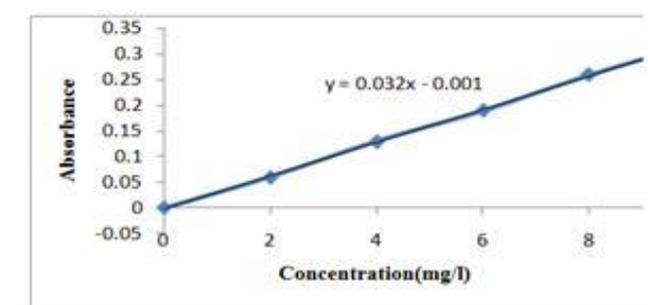


Figure 2.12 Copper Standard Calibration Curve

Source: Field Survey

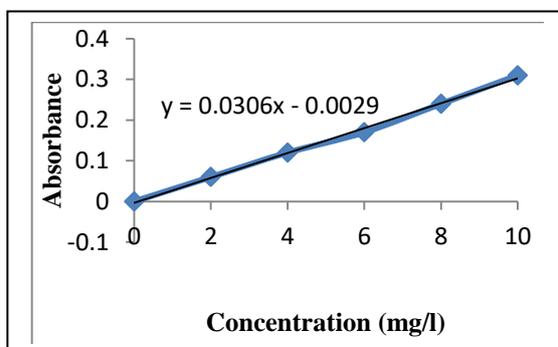


Figure 2.13 Potassium Standard Calibration Curve

Source: Field Survey

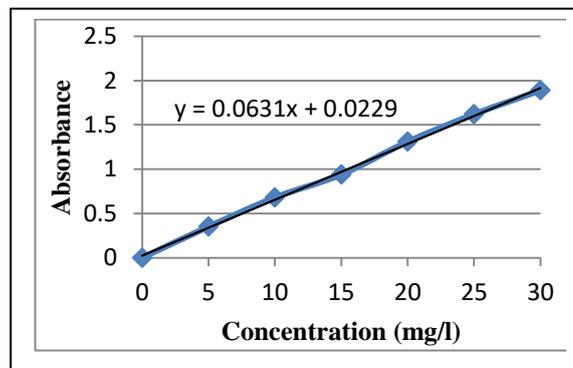


Figure 2.14 Potassium Standard Calibration Curve

Source: Field Survey

2.3.14 Data Analysis

Descriptive statistics was used in the data analysis. Microsoft Excel 2007 software was used for tables and computation of sample quality parameter means and standard deviations.

3.0 Results and Discussion

Table 3.1 is a summary of results of sampled water-boreholes in Afikpo North Local Government Area of Ebonyi State Nigeria. Twenty two physico-chemical parameters of drinking water were analysed for seven sampled water-boreholes spread across the Local Government Area. Thus 154 summary values for all the parameters and 22 mean values for specific parameters are presented. Also presented in Table 3.1 are the safe drinking water limits set by the World Health Organization (2004) and by the Nigerian Standard for Drinking Water Quality 2007. Thus table 3.1 characterizes the physico-chemical water quality of the sampled water-boreholes in Afikpo North Local Government Area of Ebony State in Nigeria.

Table 3.1 Summary of Physico-Chemical Water Quality Results of Water-boreholes A to G

S/No	Parameters WK 1-5 Summary	A	B	C	D	E	F	G	Mean	Std Dev	WHO (2004) limits	NSDWQ (2007) limits
1	pH	6.4	8.1	6.3	6.0	5.2	8.1	6.3	6.6	1.1	6.5-8.4	6.5-8.5
2	Conductivity (µS/cm)	748	74	560	586	916	410	999	613	314.9	NS	1000
3	Turbidity (NTU)	3.9	3.0	2.0	3.6	7.1	4.4	2.6	3.8	1.6	5	5
4	Colour (TCU)	4	5	5	4	5	5	4	5	0.56	15	15
5	Total hardness (mg/l)	4	52	13	5	5	8	8	13	17.30	500	150
6	Calcium hardness (mg/l)	4.28	46.12	9.00	3.92	4.74	6.38	6.10	11.51	15.36	NS	NS
7	Magnesium hardness (mg/l)	0.68	5.32	3.25	0.92	0.58	1.58	1.37	1.96	1.74	NS	NS
8	Chloride (mg/l)	8.28	29.22	13.14	8.59	11.60	7.60	8.87	12.47	7.65	250	250
9	Sulphate (mg/l)	2.17	8.36	2.69	2.26	2.02	1.57	2.96	3.15	2.34	250	100
10	Nitrate (mg/l)	0.32	2.04	0.48	0.19	0.43	0.22	0.55	0.60	0.65	50	50
11	Free Chlorine (mg/l)	0.04	0.00	0.06	0.06	0.00	0.00	0.02	0.03	0.03	NS	0.2 - 0.25
12	Fe (mg/l)	0.07	0.05	0.04	0.08	0.08	0.08	0.04	0.06	0.02	0.3	0.3
13	Mg (mg/l)	14.40	19.60	23.00	26.40	13.60	13.40	20.60	18.71	5.08	150	120
14	Zn (mg/l)	0.01	0.04	0.13	1.54	0.04	0.02	0.08	0.26	0.56	3	3



15	Pb (mg/l)	0.15	0.20	0.19	0.22	0.12	0.16	0.22	0.18	0.04	0.01	0.01
16	Ca (mg/l)	3.74	4.46	5.08	7.80	8.40	7.60	5.26	6.05	1.84	NS	NS
17	Mn (mg/l)	0.01	0.02	0.08	0.03	0.10	0.01	0.14	0.06	0.05	0.1	0.1
18	Ni (mg/l)	0.03	0.04	0.03	0.05	0.03	0.02	0.03	0.03	0.01	0.02	0.02
19	Cr (mg/l)	0.02	0.03	0.13	0.10	0.04	0.03	0.03	0.05	0.04	0.05	0.05
20	Na ⁺ (mg/l)	17.02	41.19	31.57	30.38	31.69	13.27	24.35	27.07	9.58	200	200
21	K ⁺ (mg/l)	26.95	46.16	42.50	42.02	43.61	26.37	38.20	37.97	8.08	NS	NS
22	Cu (mg/l)	0.30	0.19	0.18	0.18	0.18	0.17	0.18	0.20	0.05	2	1

Source: Field Survey

The result indicates that about 86% of the sample means are within the WHO (2004) and the NSDWQ (2007) standard limits. Lead, Nickel and free Chlorine are the only parameters which did not fall within the standard limits. The mean value for Lead is 0.18mg/l against the standard limit of 0.01 mg/l set by WHO (2004) and NSDWQ (2007). The mean value of free chlorine is 0.03mg/l which is lower than the concentration of 0.2 - 0.25mg/l that NSDWQ (2007) recommends for retention in drinking water supplies. The high levels of Lead and Nickel in the water samples might be as a result of natural contamination of ground water as there is little or no industrial/commercial activity involving Lead or Nickel in the study area. Nevertheless, high levels of Lead and Nickel in drinking water represent a significant health risk. The accumulation of lead in human body can lead to kidney failure and high blood pressure; in infants it can lead to mental and physical retardation. Nickel is a carcinogenic agent. Retention of some amount of free chlorine is a part of drinking water storage and distribution process. When water leaves the treatment plant, deliberate retention of some free chlorine can provide lasting residual protection of water from waterborne diseases through storage/distribution systems. The absence of chlorine in most of the studied samples may mostly be due to absence of water treatment by most of the water borehole operators. A major consequence of the absence of free chlorine in the samples is that even if the water is free from pathogen when leaving the water-borehole, it has no protection from microbial organisms; hence it is vulnerable to waterborne disease contamination.

4.0 Conclusion

The study has characterized the physico-chemical parameters (table 3.1) of water from some major water-boreholes supplying the inhabitants of Afikpo North Local Government Area and staff/students of Akanu Ibiam Federal Polytechnic Unwana in Ebony State Nigeria. With the exception of Lead, Nickel and free Chlorine, all the parameters examined are within the drinking water standard limits set by the WHO (2004) and NSDWQ (2007). The relatively high level of Lead of 0.18 mg/l (against the WHO (2004) and NSDWQ (2007) standard limits of 0.01mg/l), and Nickel level of 0.03mg/l (against the WHO (2004) and NSDWQ (2007) standard limits of 0.02mg/l) raise some health concerns. However, Lead and Nickel concentrations would require further investigations. The data obtained from this study can serve as baseline for continual monitoring of physico-chemical quality of drinking water-boreholes in Afikpo North Local Government Area, and thus serve as a proactive input towards the protection of public health.

Acknowledgement

We owe gratitude to the Tertiary Education Trust Fund (TETFUND) of Federal Republic of Nigeria for sponsorship of this research work. We appreciate the support of the management of Akanu Ibiam Federal Polytechnic Unwana. We acknowledge the assistance of School of Engineering Technology of Akanu Ibiam Federal Polytechnic Unwana, at both the departmental and the School Board levels.



References

- [1]. Adeleke, A., Kafeelah, Y., Olumuyiwa, O. & Mutiu, S. (2016). Classification and health risk Assessment for borehole water contaminated by metals in selected households in Southwest Nigeria. *International Journal of Pharmacology & Toxicology*, 4(2), 88-94.
- [2]. Afikpo North –Wikipedia (2019). *Afikpo North*. Retrieved from: https://en.wikipedia.org/wiki/Afikpo_North
- [3]. American Public Health Association. (1992). *Standard methods for the examination of water and waste water*. 18th ed. APHA, Washington, DC.
- [4]. Derric, L. (1995): *Ground water contamination in South Dakota*. Iles, Division of Geological Survey, Department of Environment and Natural Resources, Vermillion. Retrieved from: <https://www3.northern.edu/natsource/WATER/Contam1.htm>
- [5]. Enoh, E. A., Eneche, P. U. & Uko, N. F. (2016): Assessment of micro elements in borehole water sources in OsoEdda, Afikpo L.G.A Ebonyi state, Nigeria. *International Journal of Multidisciplinary Research and Modern Education*, 2(1), 740-747.
- [6]. Globe.(2014). *Electrical Conductivity Protocol*. Retrieved from: <https://www.globe.gov/documents/11865/354449/Electrical+Conductivity+protocol/f3841172-0e17-4e45-b52f-e68674a276e5>
- [7]. Kumolu, C. (2012): WATER CRISIS: As borehole becomes ticking time bomb? *Vanguard*, May, 9. Retrieved from: <http://www.vanguardngr.com/2012/05/water-crisis-as-borehole-becomes-ticking-timebomb/>
- [8]. Lokuge, K. M., Smith W., Caldwell B., Dear K. & Milton A.H. (1994) .The effect of arsenic mitigation interventions on disease burden in Bangladesh. *Environ Health Perspect*. 112(11), 1172-7.
- [9]. National Bureau of Statistics. (2013). *Annual Abstract of Statistics, 2011*. Retrieved from: http://istmat.info/files/uploads/53129/annual_abstract_of_statistics_2011.pdf
- [10]. Odikamnor, O., Omowaye, O. & Aneke, G. (2014). Bacteriological and chemical analysis of borehole water in Abakaliki Metropolis, Nigeria. *International Journal of Pharmacology & Toxicology*, 4(2), 88-94.
- [11]. Okeke, C.C. (2018). News14 Boreholes: Drill holes into future of environment. *Daily Trust*, December, 8. Retrieved from: <https://www.pressreader.com/nigeria/weekly-trust/20181208/281779925205211>
- [12]. Okereke, H. C., Ogbonnaya, E. S. & Eze, O. (2014): Bacteriological and physico-chemical qualities of some borehole waters in Aba South Metropolis, Abia State Nigeria. *Asian Journal of Natural & Applied Sciences*, 3(3), 83-89.
- [13]. Okogba, E.(2017). Minister expresses worry over proliferation of boreholes. *Vanguard*, March 29. Retrieved from: <https://www.vanguardngr.com/2017/03/minister-expresses-worry-proliferation-boreholes/>
- [14]. Okoye, J. I., Ene, G.I. & Ojobo, C.C. (2016). Physico-chemical and microbiological evaluation of borehole water samples in Enugu, South-Eastern, Nigeria. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 10(11), 16-19.



- [15]. PM News, (2018). *Minister urges borehole drillers to adopt National Drilling Code of Practice*. Retrieved from: <https://www.pmnewsnigeria.com/2018/11/26/minister-urges-borehole-drillers-to-adopt-national-drilling-code-of-practice/>
- [16]. Standards Organization of Nigeria.(2007). *Nigerian Standard for Drinking Water Quality*. Nigeria , Abuja : Nigeria Industrial Standard.
- [17]. United Nations Children Fund. (2018). *News note: Safe water is a right, not a privilege – for every child*. Retrieved from: <https://www.unicef.org/nigeria/press-releases/news-note-safe-water-right-not-privilege-every-child>
- [18]. United Nations Children’s Fund. (2008). *UNICEF Handbook on water quality*. Retrieved from: https://www.unicef.org/french/wash/files/WQ_Handbook_final_signed_16_April_2008.pdf
- [19]. United Nations Environment Programme and the World Health Organization. (1996). *Water quality*
- [20]. *monitoring - A practical guide to the design and implementation of freshwater quality studies and monitoring programmes*. In J. Bartram and R. Balance (Eds). Chapter 6- Field testing methods. Retrieved from: https://www.who.int/water_sanitation_health/resourcesquality/wqmchap6.pdf/
- [21]. World Health Organization [WHO], (2019a). *Health topics: Drinking-water*. Retrieved from: https://www.who.int/topics/drinking_water/en/
- [22]. World Health Organization (2019b) *Drinking-water: Key facts*. Retrieved from: <https://www.who.int/news-room/fact-sheets/detail/drinking-water>
- [23]. World Health Organization (2004). *Guidelines for drinking water quality*, (vol 1, 3rded). Geneva: World Health Organization.
- [24]. World Health Organization (2011). *Cleaning and disinfecting boreholes*. Retrieved from: https://www.who.int/water_sanitation_health/publications/2011/tn2_cleaning_disinfecting_boreholes_en.pdf